Detectors for Materials Scattering

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Scope:

- Single Crystals
- Powders
- Amorphous/Liquids
- Surfaces
- Small Angle X-ray Scattering

CCD Detectors

- Are used by many segments of the materials community
- Protein Crystallography requirements are driving the development cycle
- Special need for high-resolution CCD's for topography applications

For those experiments where a CCD is not useful:

- Large dynamic range
- Single photon counting
- High quantum efficiency
- "Good" energy resolution (e.g. ~250 eV)

Single Crystals (small molecule)

- Crystal rotation and large 2θ range needed, so area detectors less useful
- Dynamic range of utmost importance to observe bulk reflections and weak satellite peaks
- APDs are very fast, but their quantum efficiency is poor for >8 keV x-rays.
- Bede & Oxford sell fast scintillators (>500kHz)
- Often, fluorescence is an issue, ∴ energy resolution is extremely useful (~250 eV).

Single Crystals (cont'd)

Analyser crystals will always be necessary for some applications.

- Magnetic X-ray Scattering (polarization change in outgoing photon).
- Very High angular resolution (e.g. quantum well structures)
- Phase-space matching (Dumond diagram)

Single Crystals (cont'd):

- Some experiments require very good energy resolution (~30 eV), such as diffuse scattering near an absorption edge.

- The challenge is to separate the K_β resonant Raman peak and Compton scattering (v. broad in energy) from the elastic peak. Si(Li) resolution (150 eV) not good enough.

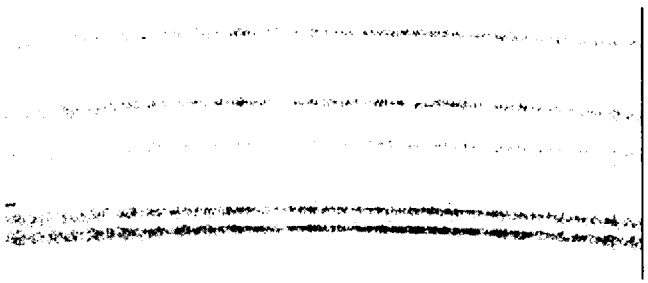
- So far, an analyser crystal has been the only solution for these situations.

Powder Diffraction

- Best resolution achieved with point detectors and analyser crystals.
- For flat plate samples, parallel collection results in significant geometric corrections.
- For capillaries, parallel collection is viable.
- Multiple point detectors (e.g. every 15°)

Powder Diff (cont'd):

- Silicon pixel detectors offer an exciting new opportunity for powder diffraction from capillary samples.



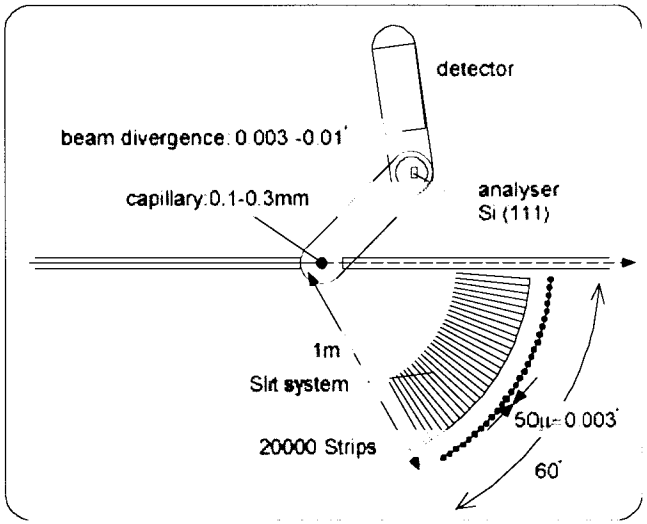


Image from Brönnimann, et al, web page abstract on a microstrip detector used for powder diffraction. http://pc2462.psi.ch/

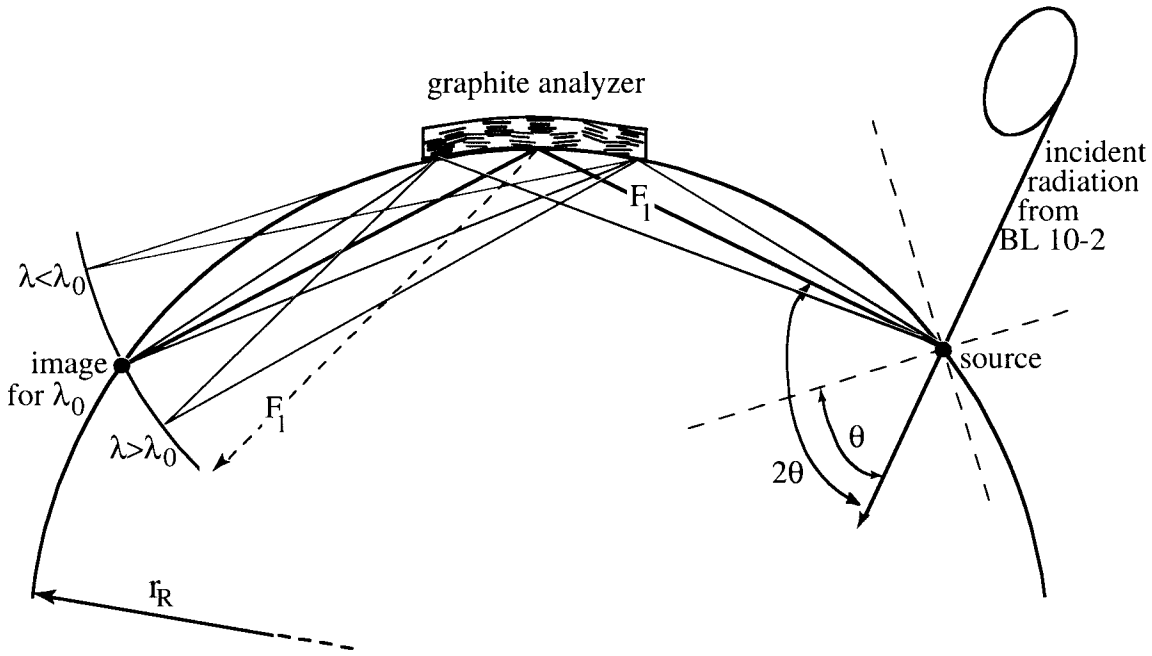
Powder Diff (cont'd):

- CCD and Image plates are currently used where entire ring useful (e.g. texture)
- Time-resolved measurements
- High pressure cell or other "Environmental" Chamber precludes angular access

Amorphous/Liquid Materials

- Anomalous scattering crucial for amorphous structural studies
- Requires separation of K_β- Raman, Compton and elastic peaks (~30 eV)
- Bent graphite analyser/Position-Sensitive Detector (PSD)
- At present, limited by PSD count rate and quantum efficiency

- Sagital focusing from bendable graphite crystal
- Parafocusing meridionally

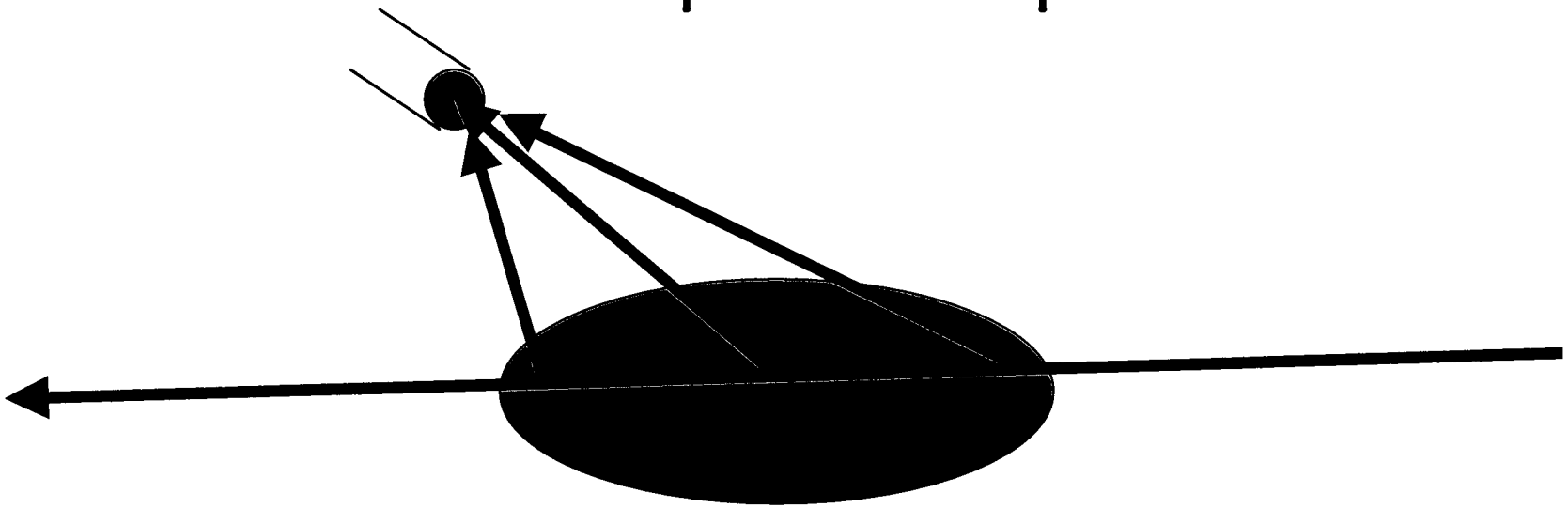


Crystal Truncation Rod Scattering

- CTR scattering has very wide dynamic range.
- Mostly point detectors and Soller slits
- Recent developments with CCD detectors (E. Vlieg, JAC 30, 532 (1997))
- Otherwise, similar to single crystal requirements

Surface Crystallography

- Incident beam paints stripe across surface, ∴ multiple source points



- Soller Slits or a crystal analyser necessary

Small Angle X-ray Scattering

- Signal levels high enough that integrating detectors work well
- CCD's and Image plates generally used
- Some very-high resolution SAXS experiments use a point detector

Summary

- CCD's effective for many applications
- High-resolution CCD's special to Mat'ls
- For the others: Single photon counting, good quantum efficiency, Fast, Good (250 eV) to Very Good (30 eV) resolution
- Probably always need analyser crystals
- Pixel detectors show real promise